Study on Active Power Filter using Real−time Hardware In the Loop Emulator

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ABSTRACT

This paper presents an algorithm for an active power filter which can be used in both single−phase and three−phase electric system. The proposed algorithm focuses on the extraction of harmonic component of load current in each phase and in order to verify the validity of the proposed algorithm while loads are nonlinear, simulations have been done by PLECS software and tested by typhoon−HIL which is real time emulator.

1. Introduction

With the increase of nonlinear loads in utility line, harmonic problem has been a primary concern. Those nonlinear loads on industrial, commercial, and residential equipment, such as diode rectifiers, thyristor converters, and some electronic circuits, which are drawing non−sinusoidal currents, pollute the utility line due to the current harmonics that they generate. They have brought about many problems in utility power, such as low power factor (PF), low energy efficiency, electromagnetic interference, distortion of the line voltage, etc. Shunt active filters arise as effective devices to compensate reactive power, harmonic distortion and unbalance currents.

This paper presents the a new control strategy of APFs for both single phase system and three−phase distribution system to compensate the distorted system current because of the nonlinear load[1]. Fig.1 shows the basic topology of APFs. In section 2, the structure of the controller is discussed. The simulation which uses the proposed algorithm was made by PLECS[2]. In the end, the controller part has been tested by TMS320F28335 DSP, and testing results is obtained from HIL.

2. The Proposed Phase−Segregated Algorithm

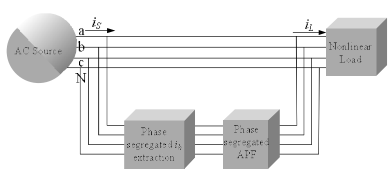

Fig.1 Three−phase power system with APFs

2.1 Zero sequence current elimination

In the three−phase system shown in Fig.1, zero sequence current is included in the three phase currents, it can be obtained by

$$i_0 = (i_a + i_b + i_c)/3 \quad (1)$$

Then zero sequence current i_0 can be eliminated as,

$$\begin{cases} i'_a = i_a - i_0 \\ i'_b = i_b - i_0 \\ i'_c = i_c - i_0 \end{cases} \quad (2)$$

After the elimination of i_0, $i_a' + i_b' + i_c' = 0$, they can be used to calculate the reference current.

2.2 Harmonic current extraction algorithm

If the three phase system is a symmetrical, we can take a single phase as example to explain the harmonic current extraction algorithm.

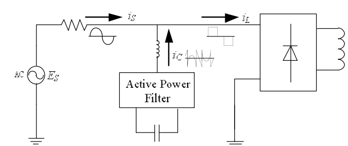

Fig.2. Single phase diagram of a power system with APFs

As shown in Fig.2, i_s is the source current, i_L is the load current, i_c is the compensate current from active power filter.

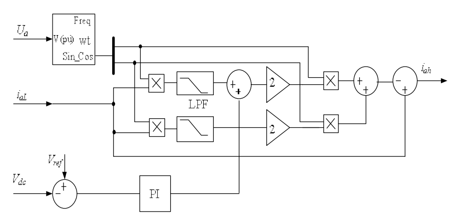

Fig.3 Active Power filter control block

Fig.3 shows the A−phase control block of active power filter. Comparing with the method of building two−phase or three−phase current method by single−phase load current, a more convenient method is proposed to achieve the fundamental current. PI controller was implemented for the DC voltage regulator so that the voltage of capacitor could operate stably. And the harmonic current i_h can be obtained as the difference of i_L and i_{s_ref}. By using the above algorithm, the harmonic component of the system current can be extracted successfully [3], and this algorithm can be extended from a single phase system to three phase system with the same principle.

3. Simulation

Both single phase and three−phase APF were made using PLECS software. Fig.4 shows the three−phase simulation circuit, the system consists of three−phase source, non−linear load, and APF circuits, which include three full-bridge inverters. The system simulation parameters are given in Table 1.

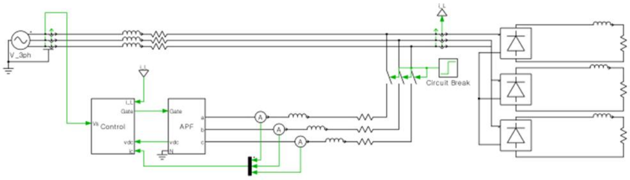
Fig. 4 Active Power Filter Simulation Circuit

Table 1 Simulation Parameters

Power System	Parameters	
AC Source	Voltage source(Vs)	220V(L-G)
	Frequency	50Hz
	Source resistance	1 ohm
	Source Inductance	10 mH
Non-linear Load	Load inductance	50 mH
	Load resistance	20 ohm
Active power filter(APF)	APF inductance	4 mH
	APF capacitance	1500 uF
	Capacitor Voltage	400V

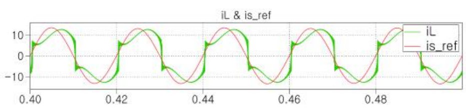

Fig.5 Load current and reference source current

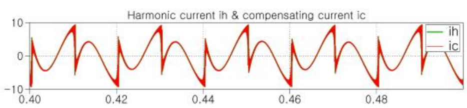

Fig.6 Harmonic current & compensate current

Fig.5 shows the load current i_L and reference source current i_{s_ref} the harmonics current can be obtained as the difference of them. Fig.6 shows the harmonic current i_h and compensating current i_c which is generated by active power filter

Fig.7 Source current waveforms

. In Fig.7, the source current waveform is shown while load inductance is 50mH and resistance is 20 ohm. While filter is operating, using the proposed algorithm can filter the harmonic current effectively by generating the equivalent current i_c, and source currents follow in sinusoidal after APFs compensation.

4. HIL Real Time Analysis

In order to verify the validity of the proposed algorithm while using real controller, the controller has been tested by typhoon-HIL which is an ultra-high fidelity and high speed real time emulator. The power stage topology is same as the PLECS simulation circuit. And the controller part was tested through TMS320F28335 DSP, The IGBT of APFs switching frequency is 10 KHz, and PI controller is used to generate the PWM signals.

The figures below were obtained from the integrated oscilloscope of Typhoon-HIL, which can provide 32Mpts record length, and 1MHz sample rate. It shows the source current i_{sa}, load current i_{La}, and compensating current i_{ca}.

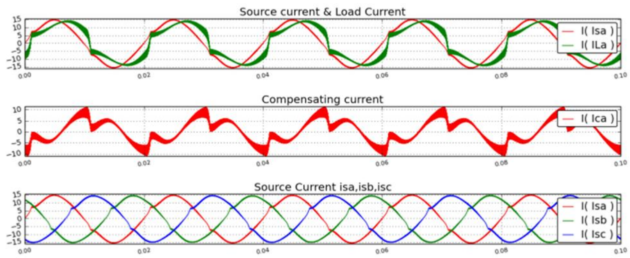

Fig.9 Hardware in the loop waveforms

While the loads of three phases are symmetrical, load inductance is 50mH and resistance is 20ohm, through the waveform, THD value of the source current was decreased from 22.3% to 4.1%. This means that APF with the proposed control strategy is quite successful.

4. Conclusion

A new convenient control strategy for shunt APFs is proposed which can be applied for single phase electric system and three-phase electric systems. Due to the symmetrical characteristic of three-phase system and the specialty of distribution system, the proposed algorithm focuses on the extraction of harmonic component of load current in each phase. The real-time hardware in the loop test results proved the validity of the proposed algorithm in power system while loads are nonlinear, the THD value can be decreased effectively. This means that APFs with the proposed control strategy is quite successful in eliminating unwanted supply current harmonics and improving the power factor.

References

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